The Geologic Storage Option

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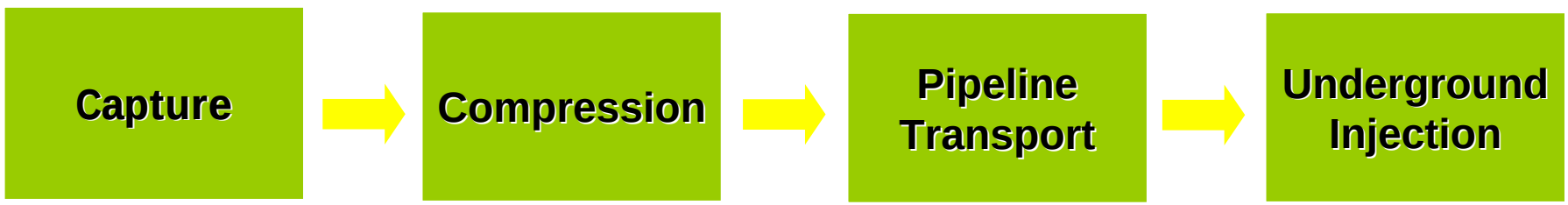
Committee Workshop on Clean Coal Technology

Topics

- Where can the CO_2 be stored?
- Assessing storage capacity
- Is geologic storage safe and secure?
- Need for monitoring
- Cost
- Mitigation strategies
- The value of pilot studies
- What's next?

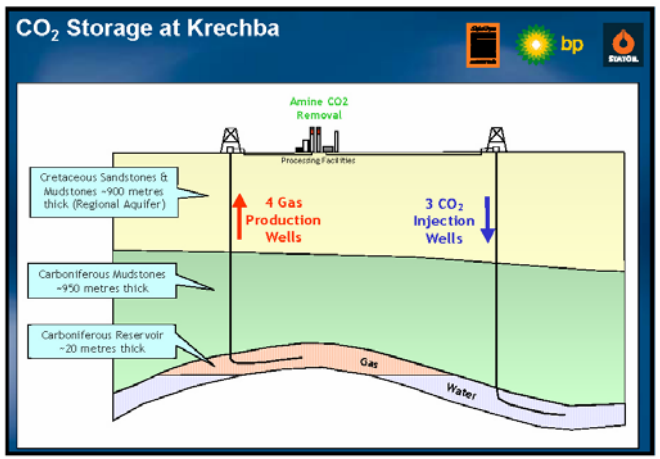
CO_2 Capture and Storage Technology

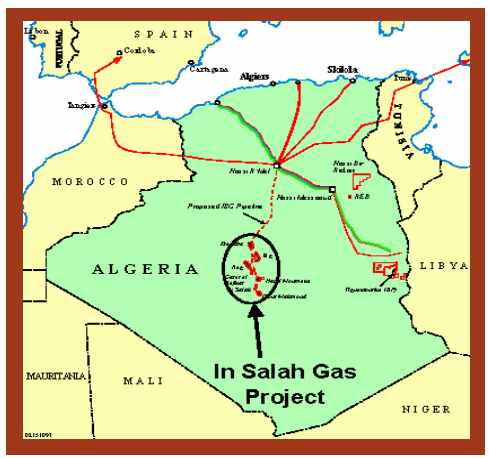
- CCS is a four-step process
  - Pure stream of CO_2 captured from flue gas or other process stream
  - Compressed to ~100 bars
  - Transported to injection site
  - Injected deep underground into geological formation (oil and gas reservoirs) and stored safely for thousands of years

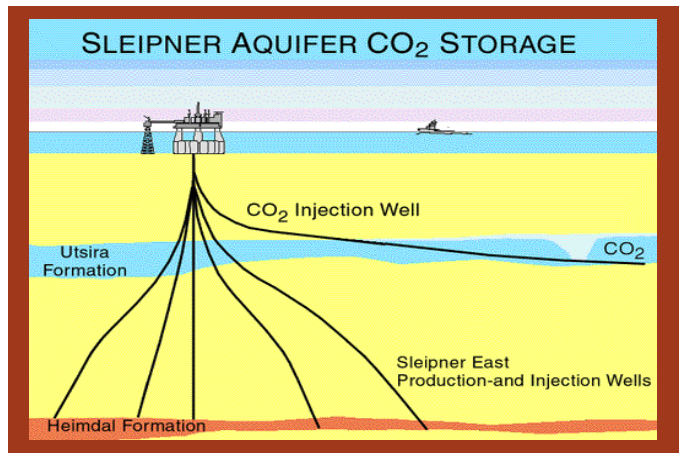


Geologic Storage Is Already Under Way

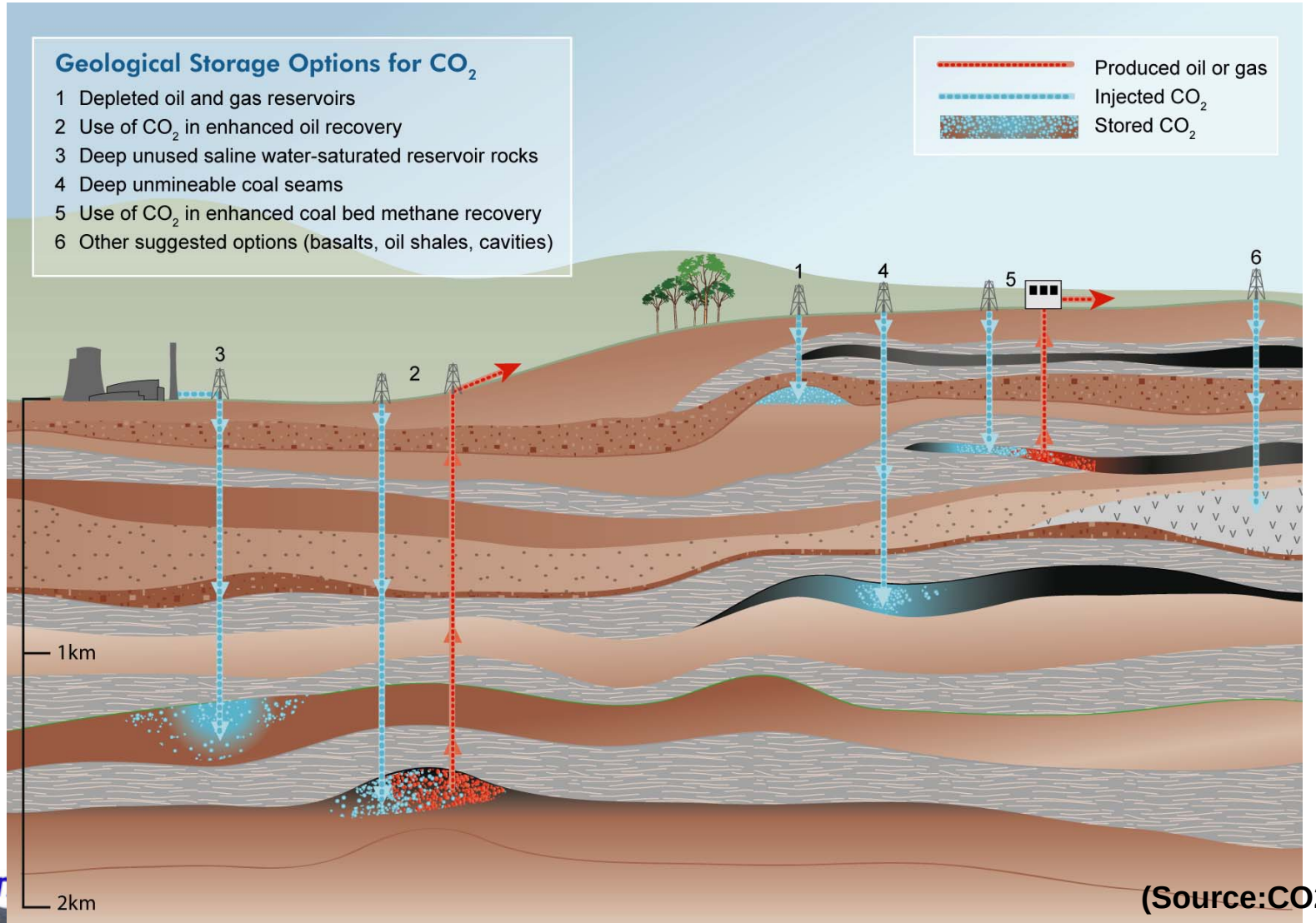
- Statoil injects $1x10^6$ tons per year at Sleipner
- BP to inject $0.8x10^6$ tons per year at In Salah







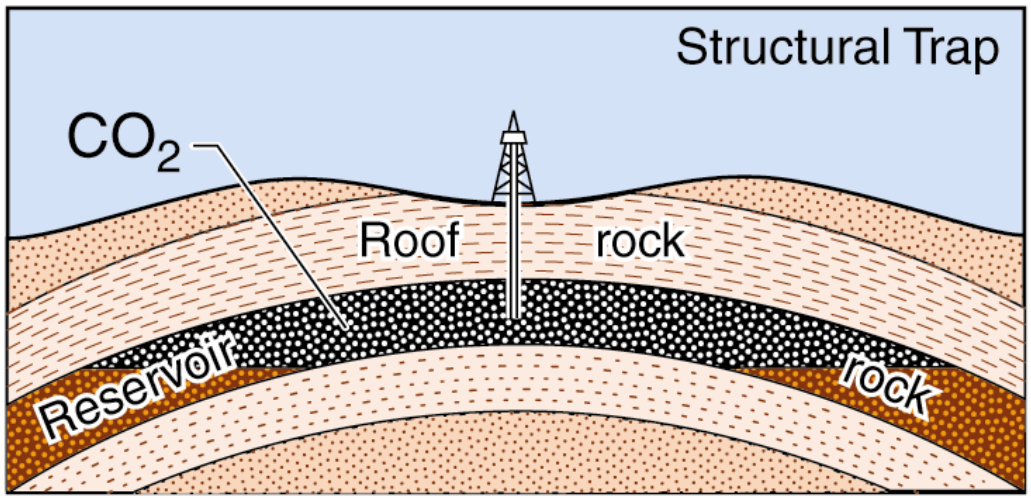
Options for Geological Storage



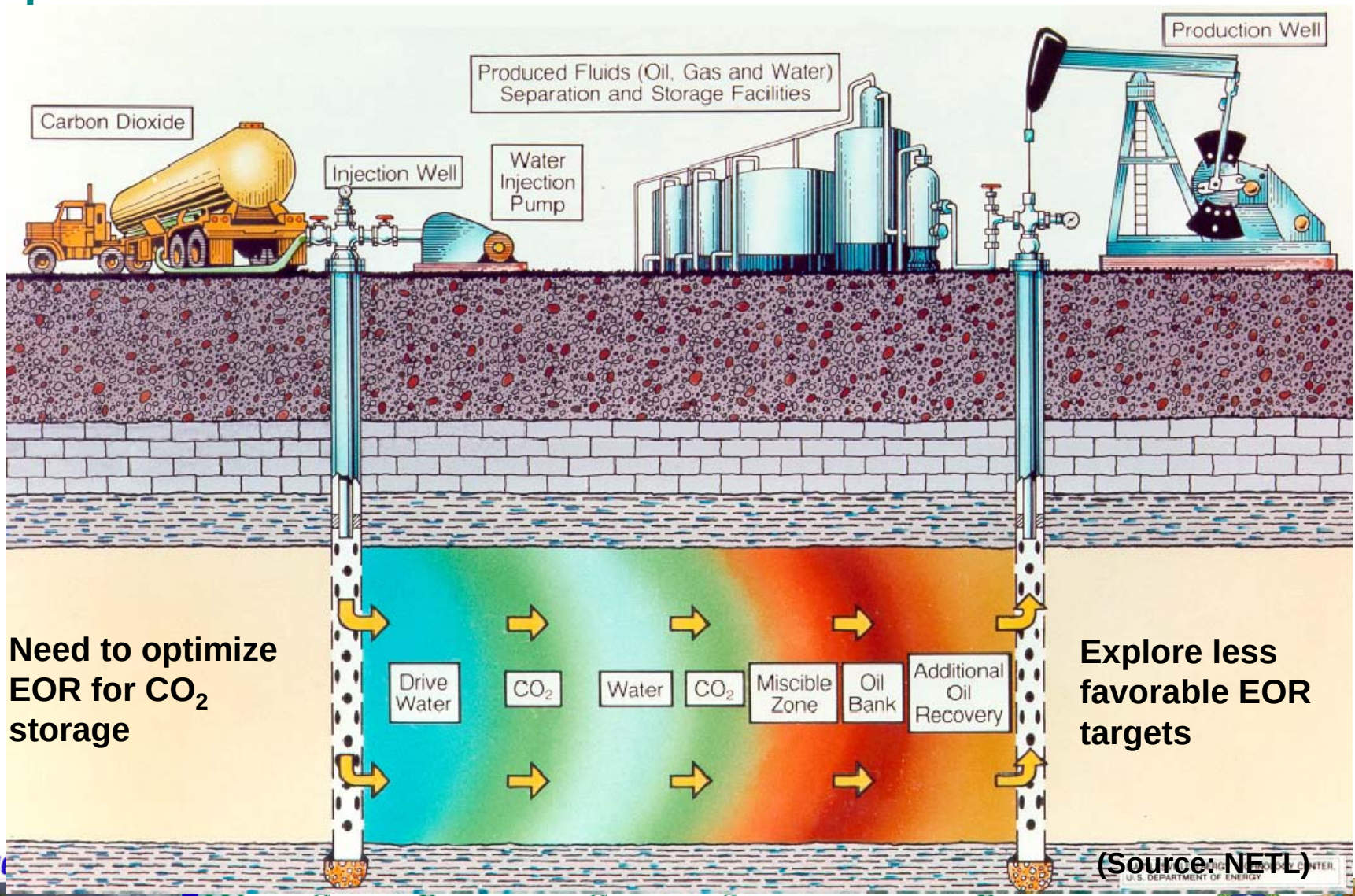
(Source:CO2 CRC)

Geologic Storage Mechanisms

- Physical, hydrodynamic, trapping
- Dissolution
- Phase trapping
- Mineralization
- Surface adsorption



CO2 Sequestration with EOR is Economic Now

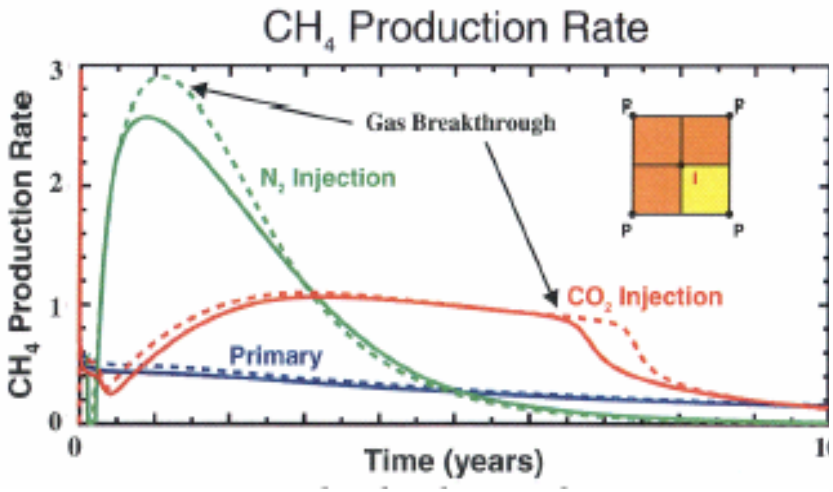


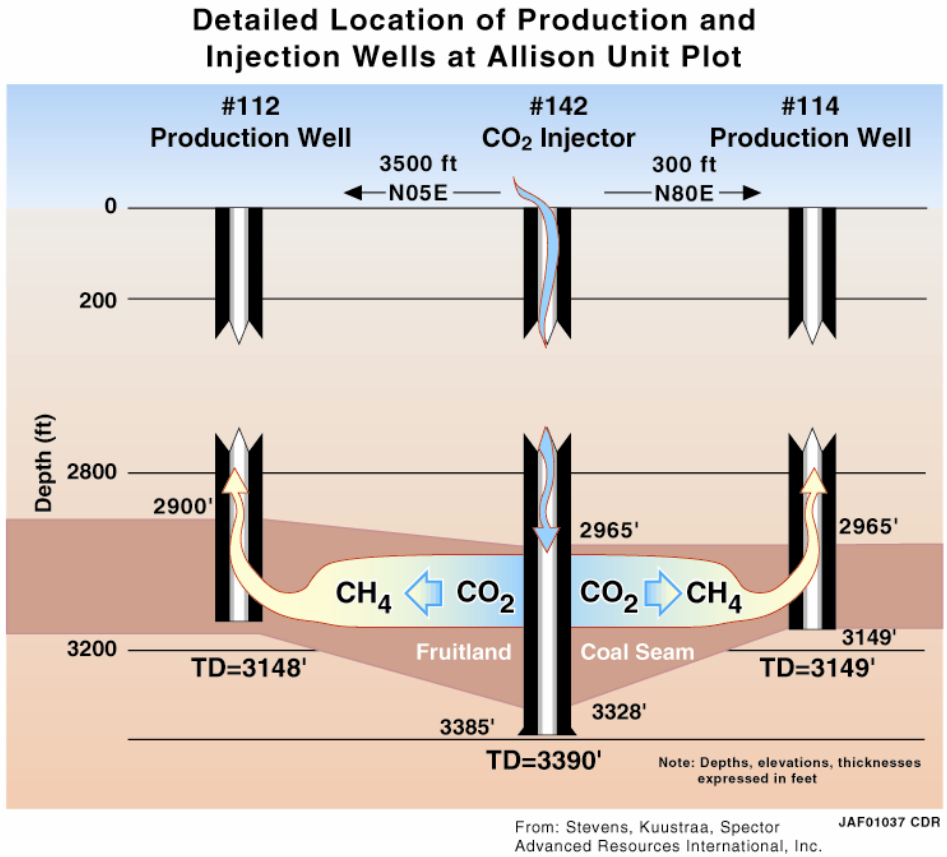
Need to optimize EOR for CO_2 storage

Explore less favorable EOR targets

(Source: NETL)

Pilots Show Coalbed Methane Production Can Be Increased While CO_2 is Stored

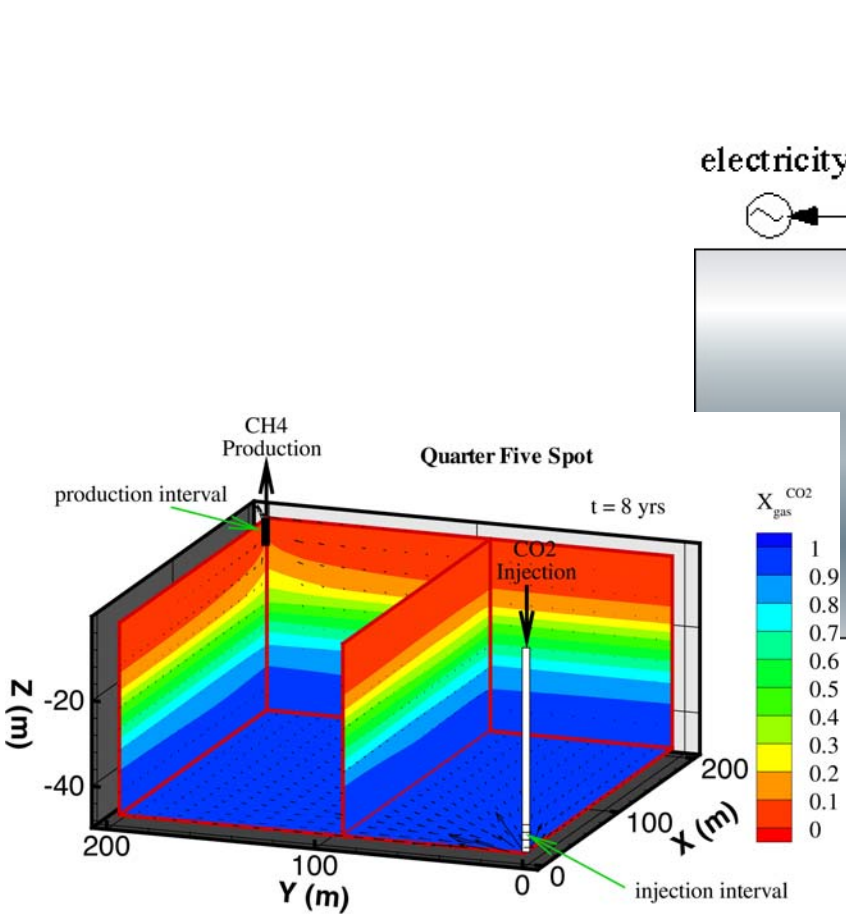


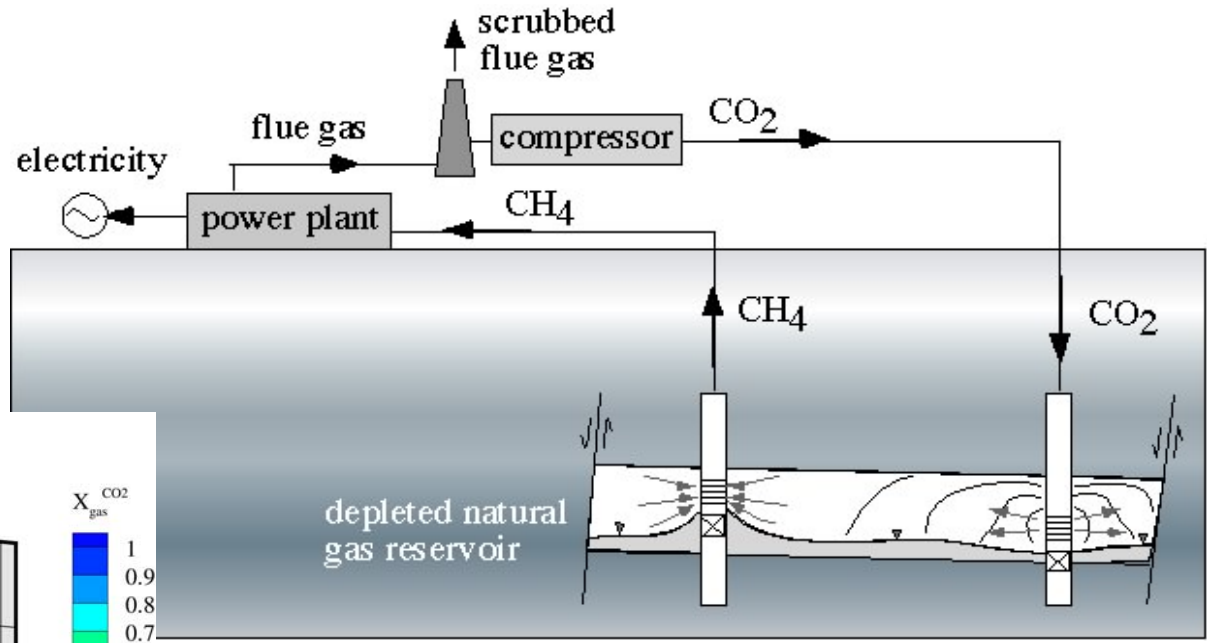


- CO_2 is preferentially adsorbed by coal, displacing CH_4
- Economics may be better if CO_2 is mixed with N_2

Stevens, et al 1998

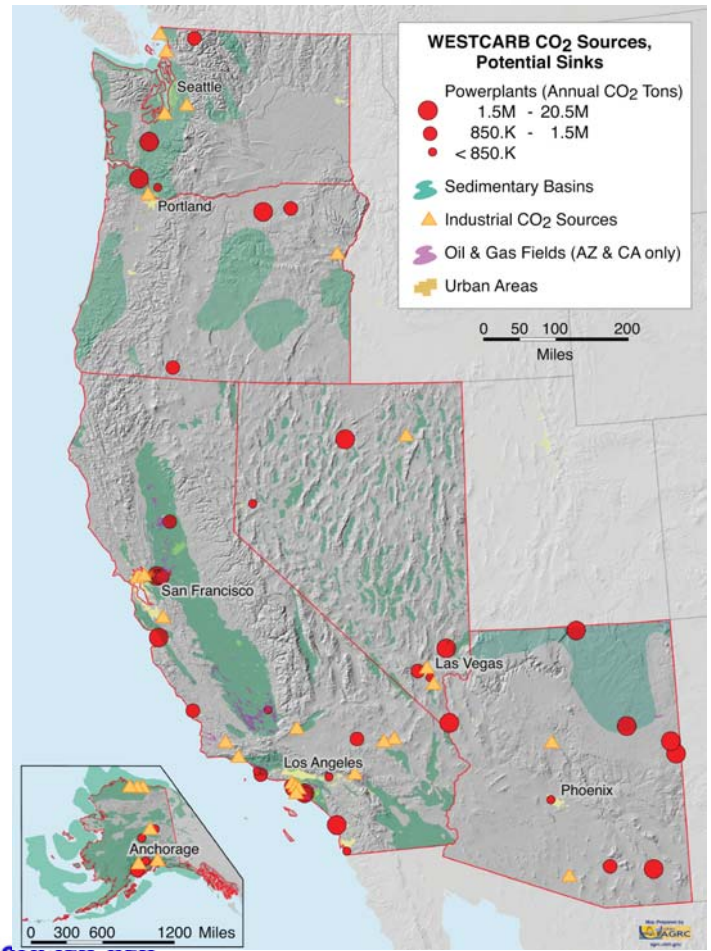
CO_2 Sequestration with Enhanced Gas Recovery has Potential

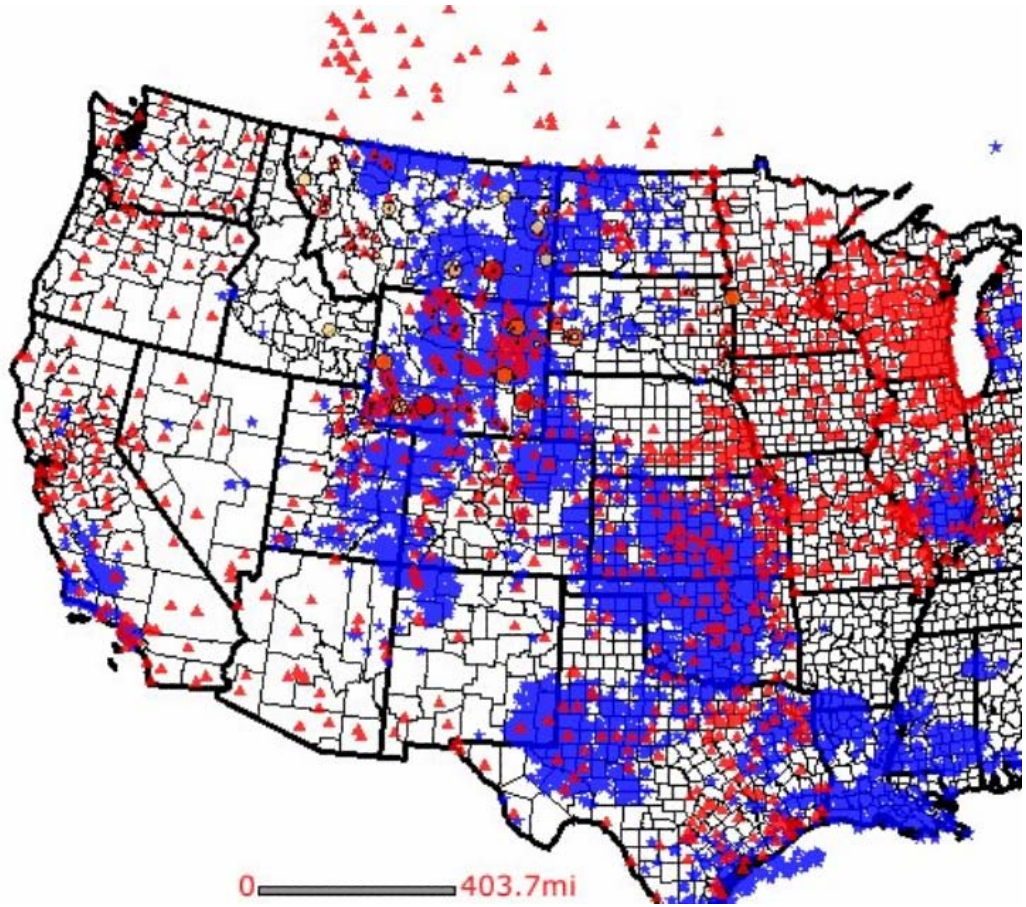




Oldenburg et al 2003

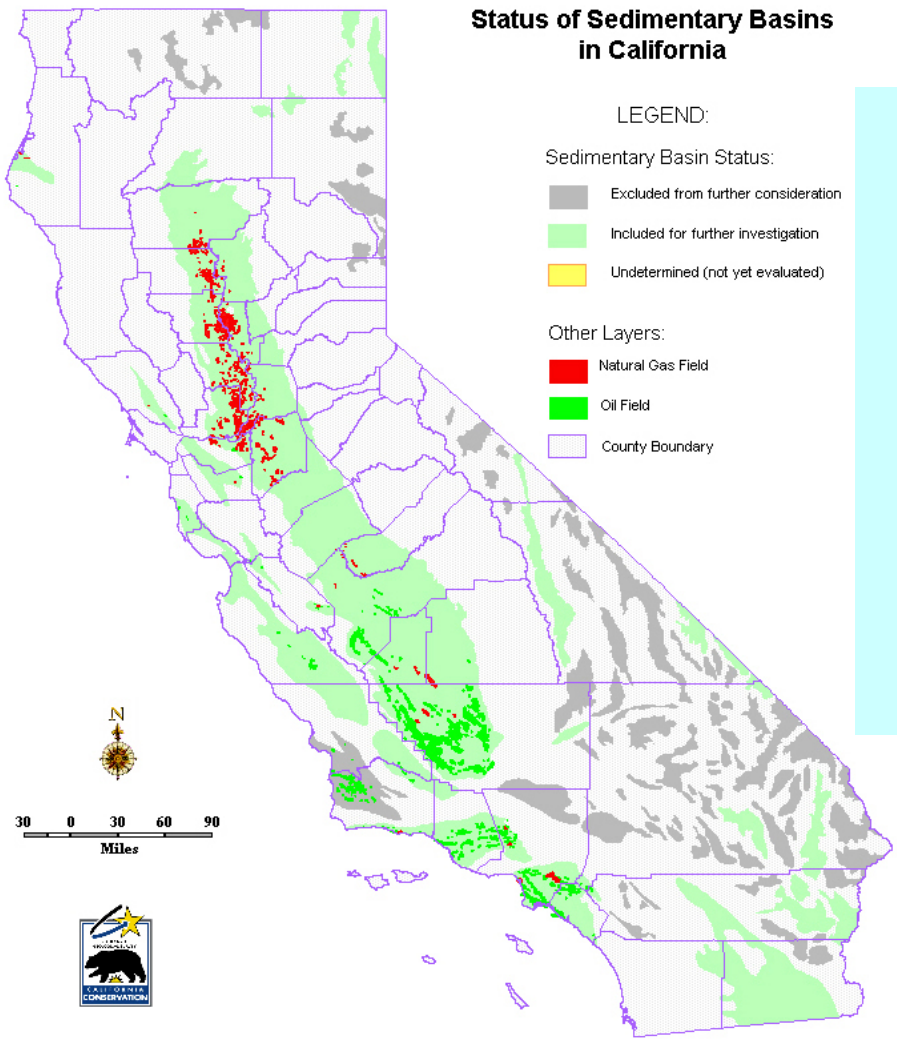
Potential Geologic Storage Formations are Broadly Distributed

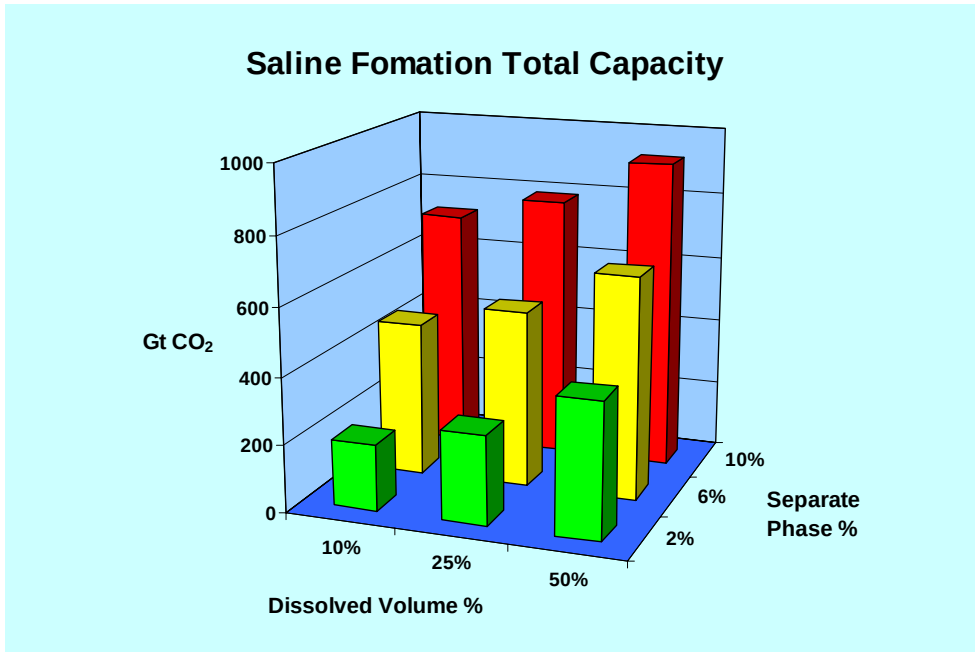




NATCARB database

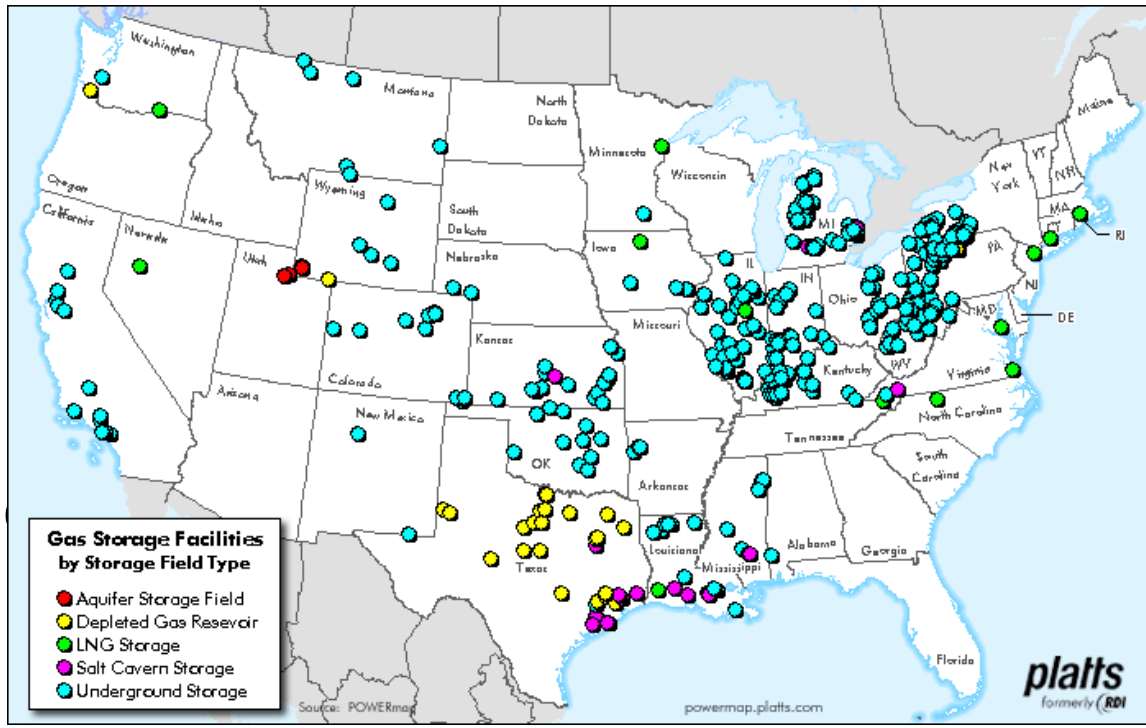
Regional Assessments Improve Capacity Estimates



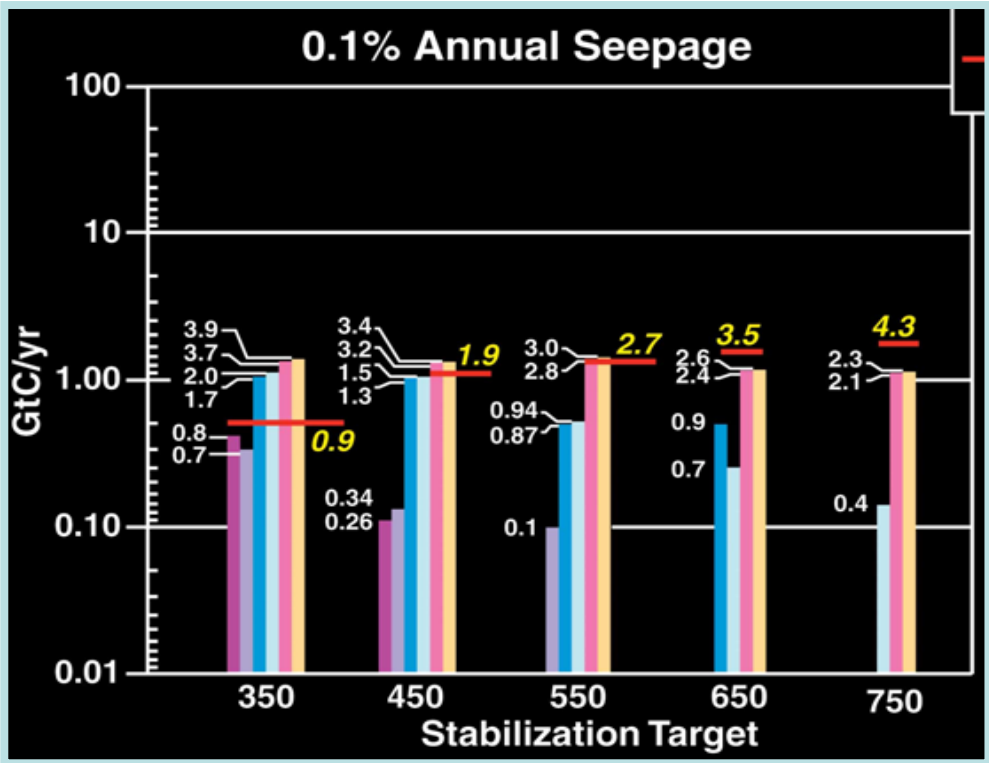


Many Lines of Evidence Indicate Storage Can Be Safe and Secure

- Natural analogues
  - Oil and gas
  - CO_2 formations
- Industrial analogues
  - Natural gas storage
  - CO_2 EOR
  - Liquid waste disposal
- Monitoring existing proje
  - Sleipner
  - Weyburn

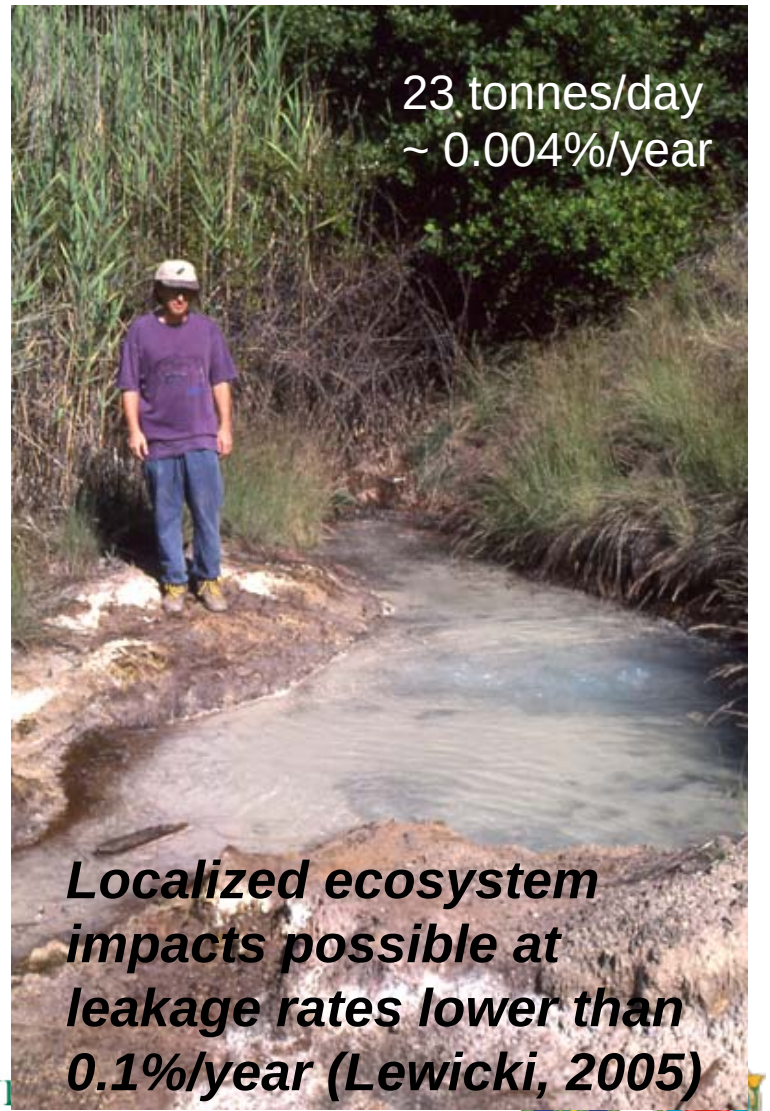


The Risk of Leakage and Its Impacts Need to be Assessed



(Benson, 2005)

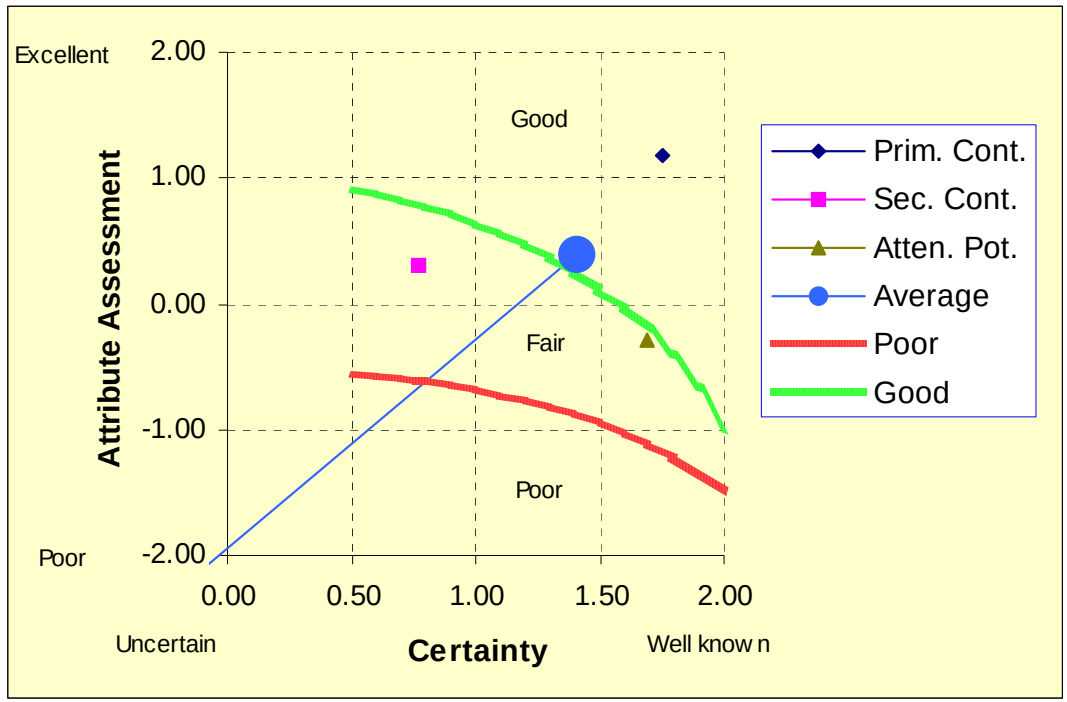
Effectiveness for Greenhouse Gas Control Require Maximum Leakage Rates of 0.1% to 0.01%/year



Localized ecosystem impacts possible at leakage rates lower than 0.1%/year (Lewicki, 2005)

Managing Risk

- Risks can be managed by
  - Careful site selection
  - Sound operational practices for well construction and injection control
  - Monitoring
  - Remediation strategies
  - Effective regulatory oversight



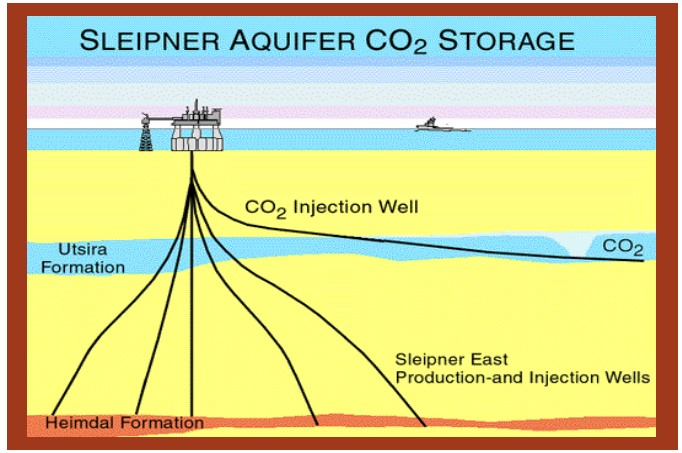
(Oldenburg, 2005)

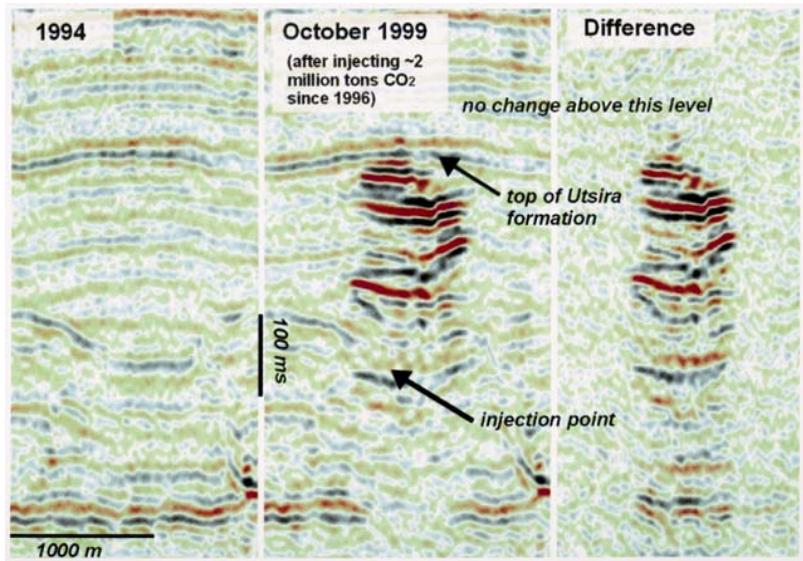
Why Monitor

- Confirm storage efficiency and processes
- Ensure effective injection controls
- Detect plume location and leakage from storage formation
- Ensure worker and public safety
- Design and evaluate remediation efforts
- Detect and quantify surface leakage
- Provide assurance and accounting for monetary transactions
- Settle legal disputes

A Substantial Portfolio of Monitoring Techniques are Available

- Seismic and electrical geophysics
- Well logging
- Hydrologic pressure and tracer measurements
- Geochemical sampling
- Remote sensing
- CO_2 sensors
- Surface flux measurements

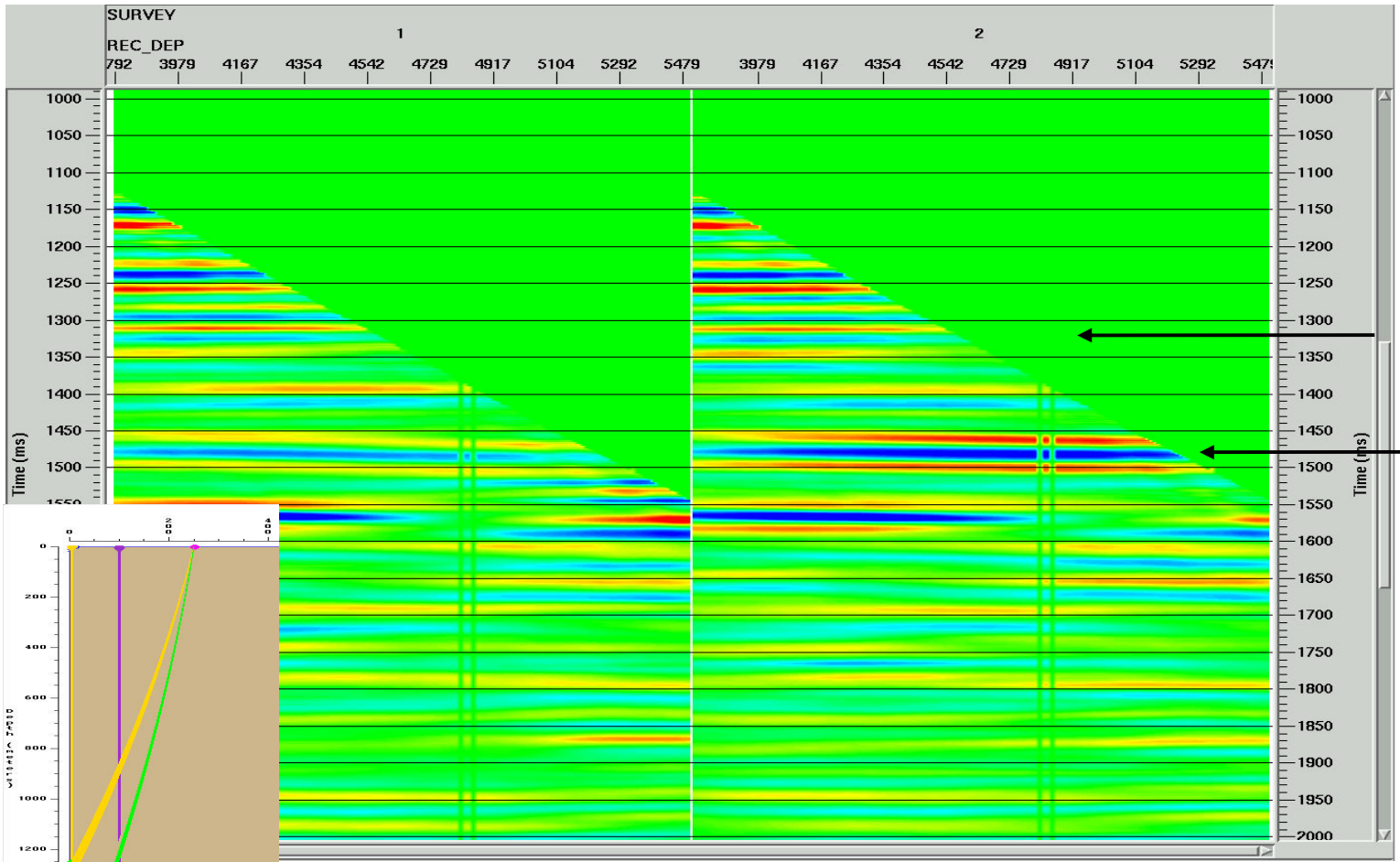




VSP Detection of 1600 tons at the Frio test

Pre Injection

Post Injection



Two-way travel time

Control Reflection

Frio Reflection

(Daley,2005)

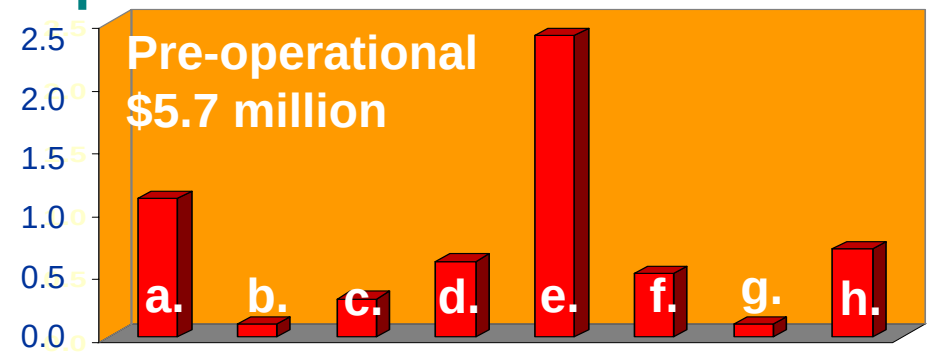
Capture is Most of the Cost of Geologic Sequestration

- Using current technology, capture is 70-80% of total cost
- New approaches are being studied
  - Capture
  - Produce concentrated CO_2 stream

Fuel	Subbituminous	Subbituminous	Lignite	Lignite	Lignite
Technology	Gasification	Amine	Gasification	Amine	Oxyfuel
CO2 Avoided, $/tonne	33.46	39.4	56.24	36.28	71.11

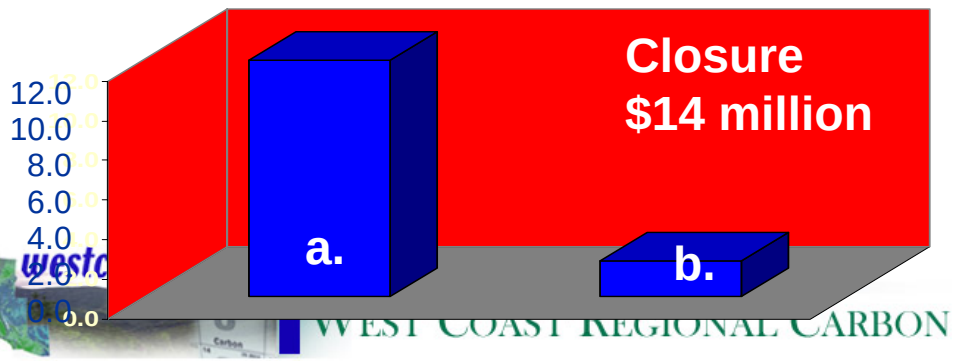
Costs are for new construction; source: EPRI

Strategies and Costs for Monitoring Saline Formations



a. Well logs
b. Wellhead pressure
c. Formation pressure
d. Injection and production rate testing
e. Seismic survey
f. Microseismicity baseline
g. Baseline atmospheric CO_2 monitoring
h. Management (15%)

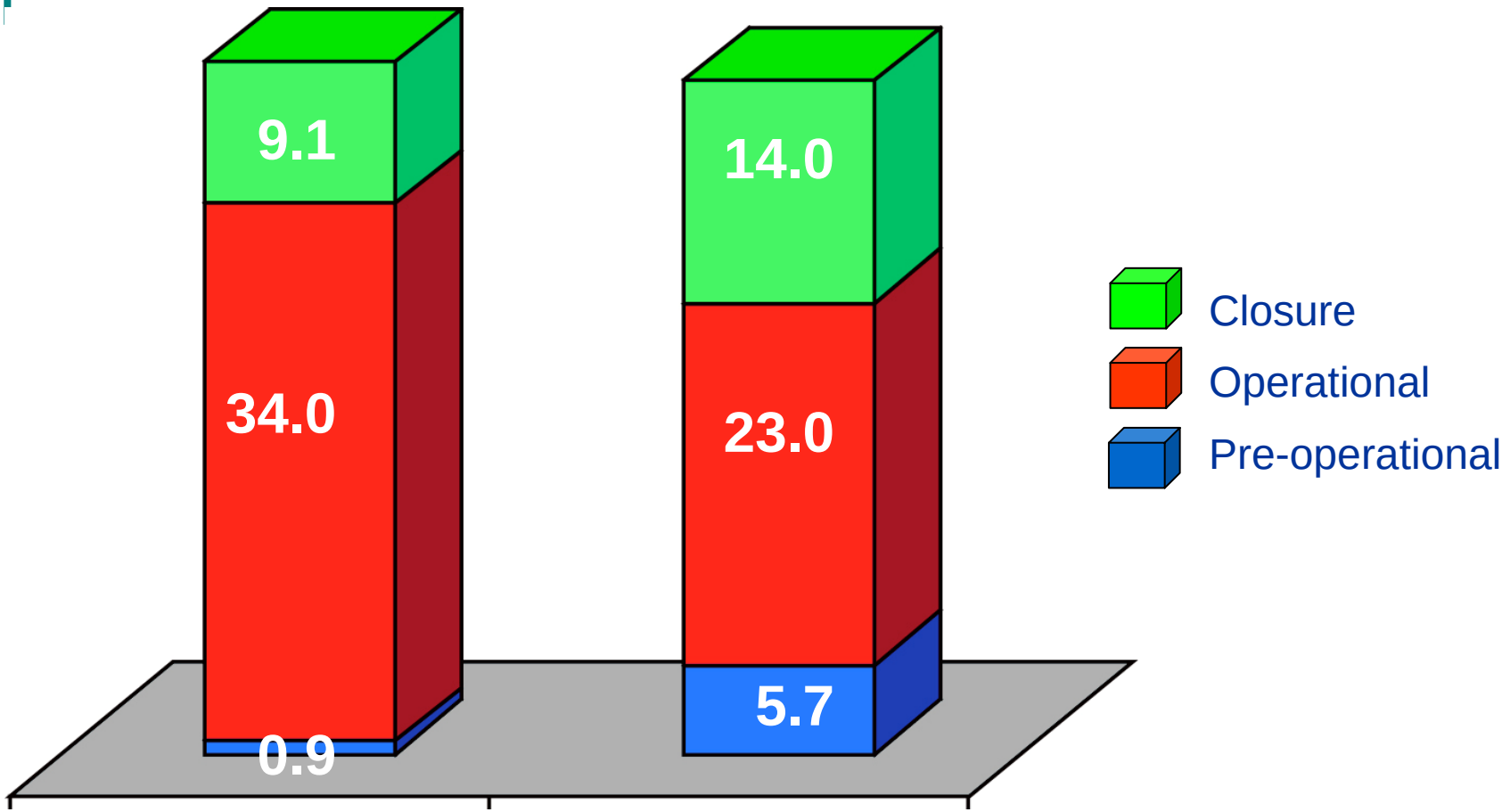
a. Seismic survey
b. Wellhead pressure
c. Injection and production rates
d. Wellhead atmospheric CO_2 concentration
e. Microseismicity
f. Management (15%)



a. Seismic survey
b. Management (15%)

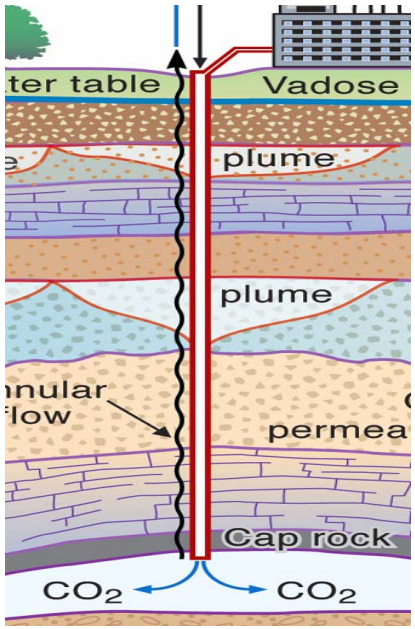
(Benson, 2003)

Comparison of Monitoring Costs

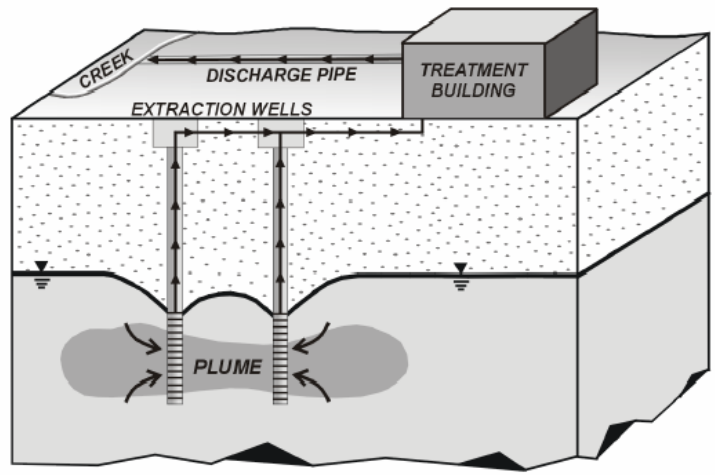


Remediation Options are Available if Something Does Go Wrong

- Leaking wells



- Lakes



- Groundwater

Picture taken from
http://www.clu-in.org/download/remed/542r012021b.pdf

Pilots Provide Regional Knowledge Base Essential for Large Scale Implementation

- Pilots demonstrate best sequestration options, unique technologies and approaches, in region
- Pilots involve site-specific focus for
  - Testing technologies
  - Defining costs
  - Assessing leakage risks
  - Gauging public acceptance
  - Testing regulatory requirements
  - Validating monitoring methods

What's Next?

- Reconciling and revising capacity estimates
- Criteria for site selection
- Best practices for well construction and injection control
- Monitoring and verification protocols
- Mitigation strategies
- Field testing to build the experience needed for full scale deployment